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EVALUATION R10-80-1

The Status of Spruce Budworms
in South-Central Alaska

Chugach National Forest
and Adjacent Lands

February 1980

U.S. Department of Agriculture
State and Private Forestry

Forest Service
Alaska Region

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INTRODUCTION

The genus Choristoneura contains about a dozen North American species of interest in forestry. These insects are forest defoliators, mostly pests of conifers. Two of the species, C. occidentalis Free. and C. fumiferana (Clem.) are among the most destructive forest pests in the United States (Bean and Mott 1972).

Larvae feed principally in expanding buds and on the current year's foliage. Their feeding can also indirectly affect developing cones resulting in poor seed production. Prolonged heavy attack can cause complete defoliation resulting in growth reduction, top kill and tree death. Most budworm species have a one-year life cycle, overwintering as a second instar. However, some budworm species have a low incidence of a second diapause (Harvey 1961) and one species, C. biennis Free., has an obligatory second diapause (e.g. two-year life cycle). The budworm species on fir and spruce can be tentatively identified but there exist numerous problems concerning their taxanomy. The following species have been identified from white spruce: C. biennis, C. fumiferana, C. occidentalis and C. orae Free.

The first recorded outbreak of the spruce budworm in western United States occurred in 1909 on Vancouver Island in British Columbia (Carolin and Honing 1972). In recent years the budworm infestations have substantially increased in the Pacific Northwest and the Rocky Mountains. Common hosts for western budworms are Douglas-fir, grand fir, white fir, subalpine fir, blue spruce, Engelmann spruce, white and Sitka spruce (Carolin and Honing 1972).

OBJECTIVES

It is believed that a more comprehensive study of spruce budworms will yield valuable insights into the present and potential budworm impact on Alaska white and Sitka spruce forests, and possible suppression measures. Accordingly, the principal objective of the 1979 study was an indepth investigation concerning spruce budworm identification(s) and life histories. For these purposes we planned:

1. To identify and delineate life cycles of the spruce budworms.

2. To determine the parasite-predator complex associated with spruce budworms.

3. To determine budworm distribution in Alaska.

4. To screen synthetic spruce budworm pheromones for possible deployment in detection measures.

PREPARATORY WORK

There is little information concerning past budworm activity in Alaska. An outbreak on Sitka spruce from Mile 0 to 59 on the Haines Highway was recorded in 1948 (McCambridge 1954). The budworm was tentatively identifed as C. fumiferana. This identification was changed later to C. orae. In 1953, white spruce in the Palmer area was lightly defoliated by an unidentified lepidoptera. The insect was tentatively identified as C. fumiferana. Budworms were observed in 1962 defoliating white spruce in the Susitna Valley (Hegg 1970). However, in all the above cases with the exception of the Haines outbreak, no species were collected. Accordingly, the determination of C. fumiferana is tenuous at best. The species determination of C. orae is assumed to be correct as samples were collected and sent to appropriate taxonomists.

1978 ground surveys detected significant spruce budworm damage to white spruce in many Anchorage residential and park areas (Anon. 1979). Likewise, budworm larvae and adults were collected in low numbers near Hope on the Kenai Peninsula and near Fairbanks. This was the first time this potentially serious conifer defoliator has been collected this far north.

Approximately 150 adults were reared from larvae collected during 1978. Specimens were sent to appropriate taxonomists[1/] and tentatively identified as:

* a form resembling C. occidentalis
* a form resembling C. biennis
* a form resembling C. orae
* a form not similar to the above three (collected near Fairbanks, Ak.)

Approximately 100 larvae were separated according to head capsule and prothoracic shield coloration (Harvey and Stehr 1967). These Anchorage larvae were considered to be either C. orae or C. biennis (Harvey, Personal Communication, 1978). C. occidentalis appeared much less likely as the nearest known occurence of this species is below 52° north latitude.

Identification of the Alaska budworms is uncertain. The discrepancies and differences in species identifications are in part due to the fact that reclassification of the Choristoneura complex is now underway. Also, the number of Alaska budworm specimens sent for species determination(s) was limited. It was thus felt that with a larger, more diverse budworm rearing program, specific determinations could be made.

1/ D.C. Ferguson, Insect Ident. and Benef. Insect Introd. Instit., Beltsville, Maryland and A. Mutuura, Biosystematics Research Institute, Ottawa, Canada.

MATERIALS AND METHODS

A. STUDY AREA

The major part of the 1979 studies were concentrated in heavily infested white spruce located in the Anchorage Denali Park Strip and surrounding residential areas. These areas provided adequate rearing material throughout the field season.

B. BUDWORM IDENTIFICATION AND BIOLOGY

1. Approximately 150 budworm larvae were collected weekly from infested spruce beginning mid-May. About half the collected larvae were placed in alcohol; at a later date, head capsule widths were measured to the nearest hundredth millimeter for instar determination. The remaining 75 larvae were placed in laboratory rearing cages (five larvae per cage) provided with host foliage.

   Pupae and emerging adults from the rearings were measured. Associated parasites were collected and sent to appropriate specialists for identification.

   Time of adult mating was investigated using a Biotrenette Mark II environmental chamber. Temperature and relative humidity were maintained at 20°C. and 70 percent, respectively. A 16 hour photoperiod was used. Twenty-one pairs of recently emerged adults (one pair per cage) were observed. Occurrence of mating was recorded every one-half hour.

2. An oviposition preference study was undertaken in early August. At this time budworm egg masses have eclosed and appear whitish against the green foliage. Five white spruce trees were each divided into four sections: lowest branch tier, approximately six feet above ground, mid-upper crown and the upper crown. Each of the four sections was divided into four quadrants (north, south, east, and west). One 18" branch was clipped from each of the sections (16/tree) and returned to the laboratory. Each branch was divided into an exterior and interior section (interior being nearest the bole) and the number of budworm egg masses was counted.

3. Insect attractants (sex pheromones) are another means of establishing the identity of spruce budworms. Sanders (1971) demonstrated that the sex pheromone of C. orae is different from that of C. fumiferana, occidentalis and biennis which share a common attractant. 150 late instars were sent to Drs. G.T. Harvey and C.J. Sanders of the Canadian Forestry Service (Sault Ste. Marie, Ontario) for adult rearing and cross-attracting tests.

4. Dr. Molly Stock, College of Forestry (Univ. of Idaho), is undertaking an electrophoretic study of spruce budworms. One of the projects is the identification of diagnostic isozyme patterns which can be used as species markers for spruce budworm studies. Apparently the major species can already be distinguished utilizing this technique. 200 late instars were collected in Anchorage and shipped to Idaho for genetic determination.

C. DISTRIBUTION OF ALASKA BUDWORMS

1. Preliminary studies undertaken in 1978 indicated some budworm activity in Hope, Alaska (Kenai Peninsula) and in the Bonanza Creek Experimental Forest (near Fairbanks). It was assumed that budworms exist between these two widely separated localities and that the deployment of synthetic pheromones would be a good beginning in delineating budworm distribution throughout Alaska.

   Synthetic sex attractants are widely used in insect distribution, suppression and monitoring studies, especially with the Lepidoptera. Traps baited with a specific attractant will lure males of a given species if the traps are placed in the field during adult flight. In 1978, studies indicated that Alaska budworm adults are active during mid-July. Dr. Gary Daterman of the USDA Forestry Sciences Laboratory (Corvallis, Ore.) provided us with enough synthetic pheromone (P.V.C. formulated) to make up 72 trap baits. The pheromone used was trans-11-tetradecenal, 1 percent by weight; the sex pheromone of C. fumiferana, C. occidentalis and C. biennis (Sanders 1971, Weatherston et al. 1971, Sanders and Weatherston 1976). As previously mentioned, this specific attractant will not lure C. orae. During the second week in July (1979) 72 Pherocon-2^{R} traps were placed in twelve white spruce stands (pole size to mature trees) from Homer (on the tip of the Kenai Peninsula) to Delta Junction (near Fairbanks). Six traps were placed in each stand and left for approximately two weeks. All trapped budworm adults were removed, recorded, sexed and sent to taxonomists for species determination(s).

2. All infested white spruce were mapped in the downtown residential areas of Anchorage.

RESULTS AND DISCUSSION

A. LIFE STAGES:

ADULT: The adult spruce budworm is a medium sized moth; about 1.2 cm long with a wing span of 2.49 cm. for females (n=82) and 2.30 cm. (n=80) for males (females significantly larger than males, Students "t" test @ .05). A variety of forewing patterns and color were observed which is not unusual for budworm species. From a sample of 38 females and 25 males, frequency of brown moths was 55 percent in females; none of the males could be classified as brown but among the grey males there was a high proportion of brown scales. A frequency of 55 percent brown females clearly exceeds that expected for C. fumiferana or biennis and is close to that found for orae and occidentalis (Harvey-Pers. Comm. 1979).

1. Mating: Twenty out of the twenty-one budworm pairs mated on the same day of emergence; the majority between 11 am. and 12:30 pm. The remaining pair mated the day following emergence. This finding is similar to the mating behavior determined by Sanders and Lucuik (1975) for Canadian budworms. Only 8 egg masses resulted from the matings; these were deposited from two-to-four days after mating.

EGGS: The budworm lays its eggs in masses on the host needles, generally on the twig tips within a few inches of the buds or defoliated areas. The light green eggs are approximately 1 mm long by 0.2 mm wide deposited in masses of an average of 20, over lapping one another (Bean and Mott 1972). Hatching occurs in about 10 days (Thompson 1979). After eclosion, the egg masses are white-grey in color and are easily detected on host foliage.

LARVAE: The first instar is yellowish green, 2 mm long, with a light-brown head. The second instar is similar in coloration to first instar. The body color of the succeeding four instars changes from a pale yellow to a dark brown with light colored spots along the back. Mature larvae are approximately 2.5 cm long with dark brown heads (Bean and Mott 1972). Mean head widths of the six budworm instars from Alaska are given in Table 1 and are comparable to the findings of Bean and Batzer (1957) for Canadian and Minnesota budworms.

Table 1. Head Capsule Measurements (in mm) of Spruce Budworm Larvae

Instar	No. of Larvae	Mean Width
1	70	0.23
2	4	0.40
3	37	0.55
4	53	0.82
5	46	1.19
6	129	1.62

PUPAE: Newly-formed pupae are pale yellow, darkening with age to reddish brown to black. They are broad at the head end but tapering rapidly toward the tail. Mean length and width for male pupae (n=61) are 10.38 mm (s.d. 1.71) and 2.89 mm (s.d. 0.62), respectively. For female pupae (n=61), mean length and width are 10.82 mm (s.d. 1.77) and 3.38 (s.d. 0.70), respectively. Female pupae are significantly greater in width than males but not in length (Students "t" test, @ .05). Spruce budworm pupae can easily be sexed by the location and shape of the genital opening. In females, the genital pore is found on the 8th abdominal segment, whereas in males, the pore is located on the 9th segment (Jennings and Housewoart 1978).

Pupal rearings produced 336 adults (67 percent success). Eighty percent of adult emergence occurred after six-to-seven days.

B. LIFE HISTORY

1. General Life Cycle: The majority of budworm species with the exception of C. biennis, have a similar one year life cycle (Furniss and Carolin 1977, Bean and Mott 1972). Eggs are deposited in June and July and hatch in about 10 days. Newly hatched larvae do not feed but spin silken shelters among lichens, bud and bark scales. The young larva transforms into the second instar and remains within the shelter throughout the winter. The next spring, about mid-May, the larvae bore into expanding buds and feed upon new needles. Later, the developing larvae loosely web the new growth and feed upon the new needles. New foliage is preferred and is entirely destroyed before the old growth is eaten.

The larvae then transform into pupae. In Alaska this generally occurs about mid-to-late June. Pupation sites are generally within the last formed larval webbing. However, pupae may be found at twig axes.

Adults emerge in six to ten days and are active throughout the late afternoon and early evening. Adults can be carried up to ten miles by normal winds or hundreds of miles by storm fronts (Bean and Mott 1972).

2-year Budworm (C. biennis): Eggs are laid in even numbered years and the larvae overwinter as second instars. The following summer they develop to the fourth instar and again overwinter. The third spring they complete their 2-year cycle. Adults are darker and slightly larger than C. occidentalis (Furniss and Carolin 1977).

2. Developmental Rates of Alaska Budworm: Preliminary observations in 1978 indicated two "distinct" instars feeding at the same time. Likewise there was variation in time of adult emergence and adult size. It was felt that, in Alaska, we either have one budworm species with substantial variation in adult, pupal and larval sizes or the Alaska budworm population is composed of two species. British Columbia budworm likewise have rather large size differences within a single area (Harvey - Pers. Comm. 1979). Due to peculiar weather patterns, emergence from overwintering sites has been known to occur in Canada during periods separated by as much as two weeks. Usually the later emerging larvae catch up in size but not always. This may partially explain the developmental differences observed in 1978 Anchorage populations.

Of 160 late instar budworms sent to the Great Lakes Forest Reserch Center (Ontario, Canada), five percent entered a second diapause. The occurrence of a second diapause, although almost universal in C. biennis, is not totally diagnostic, as this behavior occurs occasionally in three other species (Harvey 1967).

Figure 1 depicts the percent of a given instar as related to day of larval collection in 1979. If the Alaska budworms, whether one or more species, had a one year life cycle, the "high" percentages of fourth and fifth instars would not be expected during mid-May. Large larva at this time are more indicative of the two-year budworm, C. biennis, which overwinters a second time as fourth instar larvae. Thus, it appears that a portion of the budworm complex could be C. biennis; the remaining species have yet to be determined.

3. Budworm Oviposition: An average of 52 egg masses per tree were counted on the five white spruce sampled for budworm oviposition perference. There were no significant

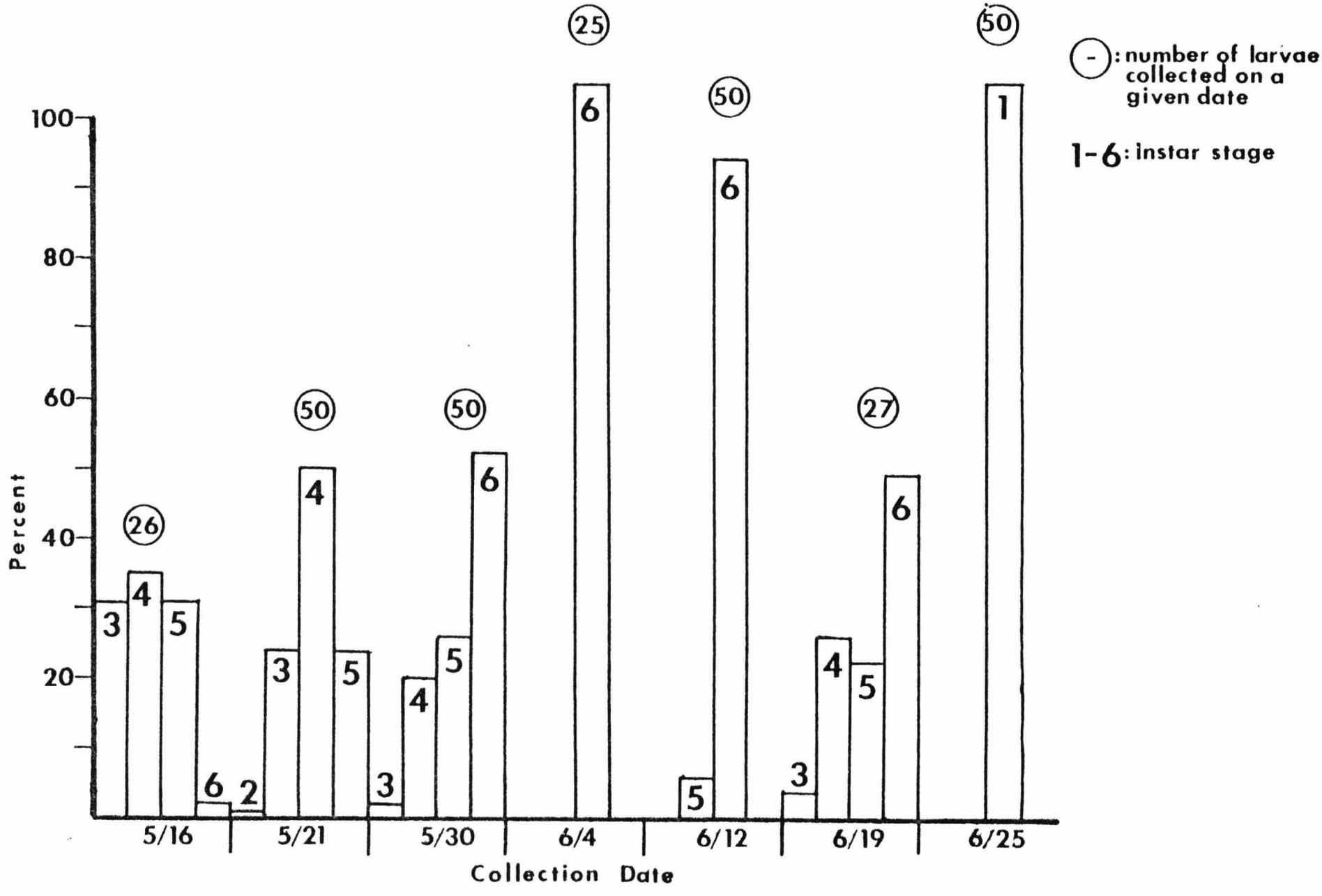

Figure 1. Prevalence of an Instar Stage (in percent) as

differences (one-way ANOVA, F-test, @ .05) between numbers of egg masses and quadrant, branch levels or interior vs. exterior branch sections. However, at the 0.20 significance level, there were more egg masses on the exterior branch section (branch tips) than on the interior section, (150 vs. 109).

4. Budworm Sex Pheromones (Great Lakes Forest Research Center): Adults developing from the collections sent to Canada in 1979 matured too late for field testing to compare pheromone responses. Future evaluation is planned for 1980.

5. Isoenzyme Frequencies (Univ. of Idaho): Preliminary results of the isoenzyme frequency study indicated that Alaska budworms are, in overall genetic makeup, similar to C. occidentalis (Western Spruce Budworm) and clearly different from C. fumiferana (Eastern Spruce Budworm, material from Maine) (Stock-Pers. Comm. 1979). However, Stock (Pers. Comm. 1979) raised the question that a cline might occur over the range of C. fumiferana as it spreads in a westward direction. That is, western most populations of C. fumiferana might be closely related to the western C. occidentalis. We hope to answer such questions in 1980 studies.

6. 1979 - Alaska Budworm Rearings - Parasites and Predators: A total of 258 larvae were placed in laboratory rearings of which 222 (86 percent) were successfully reared to the pupal stage. 24 died (9 percent) from unknown causes and 12 larvae (5 percent) were parasitized. 499 pupae were reared and 336 adults emerged (67 percent success). Parasitism accounted for 20 pupae (9 percent) and 143 (29 percent) died from unknown causes. Parasites tentatively identified by R.D. Averill include:

Braconidae

Meterous sp. uncommon
Apanteles possibly A. aristoteliae (Vier.) abundant
and possibly A. fumiferanae (Vier.) common

Ichneumonidae

Glypta possibly G. inversa (Cresson) common

Ichneumoninae possibly Horogenes uncommon
Phaeogenes hariolus (Cresson) uncommon
Lissonota sp. common

Porizonitinae 2 species common

Pteromalidae

Mesopolobus possibly M. verditer (Norton) uncommon

Tachinidae

Omotoma sp. common

Specimens are being verified by taxonomists at the U.S. National Museum.

C. DISTRIBUTION OF ALASKA BUDWORMS:

1. Pheromone Trapping:

Approximately 50 male budworms were trapped in the Anchorage area. The only other traps which successfully lured adult budworms were located in a pole-sized white spruce stand in the Copper River Basin (62° 17', 143° 23'): nineteen males were trapped. Final species determinations have not yet been undertaken for these adults.

Even though no adults were lured to the other traps, this does not necessarily mean budworms do not exist in these areas. Budworm pupal cases were collected near Cooper River Landing (Kenai Peninsula) even though traps in this general area failed to lure adults. As previously mentioned, the attractant which was used lures only C. occidentalis, C. biennis and C. fumiferana but not C. orae.

1980 budworm studies will continue with pheromone trapping and will incorporate C. orae attractants.

2. Mapping of infested spruce in downtown Anchorage indicated that the heaviest affected areas are near the Denali Park Strip and vary in intensity throughout the surrounding area (Figure 2). It is not known why budworm activity is so prevalent in one area; however, (1) there is the possibility that the budworm is a fairly recent introduction, via ornamentals into this area and has not had time to disperse; (2) another possibility is budworm populations have existed in Alaska for a long time and are normally maintained at low levels through the actions of parasites, predators and weather. Periodically, field populations may increase as occurred in 1948, in the Haines Highway area. However, budworm populations in urban areas may be more damaging due to the stressed condition of ornamentals and the ineffectiveness of parasites and predators due to urban pollution (e.g. dust, car exhaust, etc.); and (3) June-July temperatures might be too low, for active adult dispersal yet adequate for oviposition. Thus, resident populations might be held in an area by cooler temperatures which prevent take-off and dispersal flight; a build-up of local populations may result (Sanders et. al. 1978).

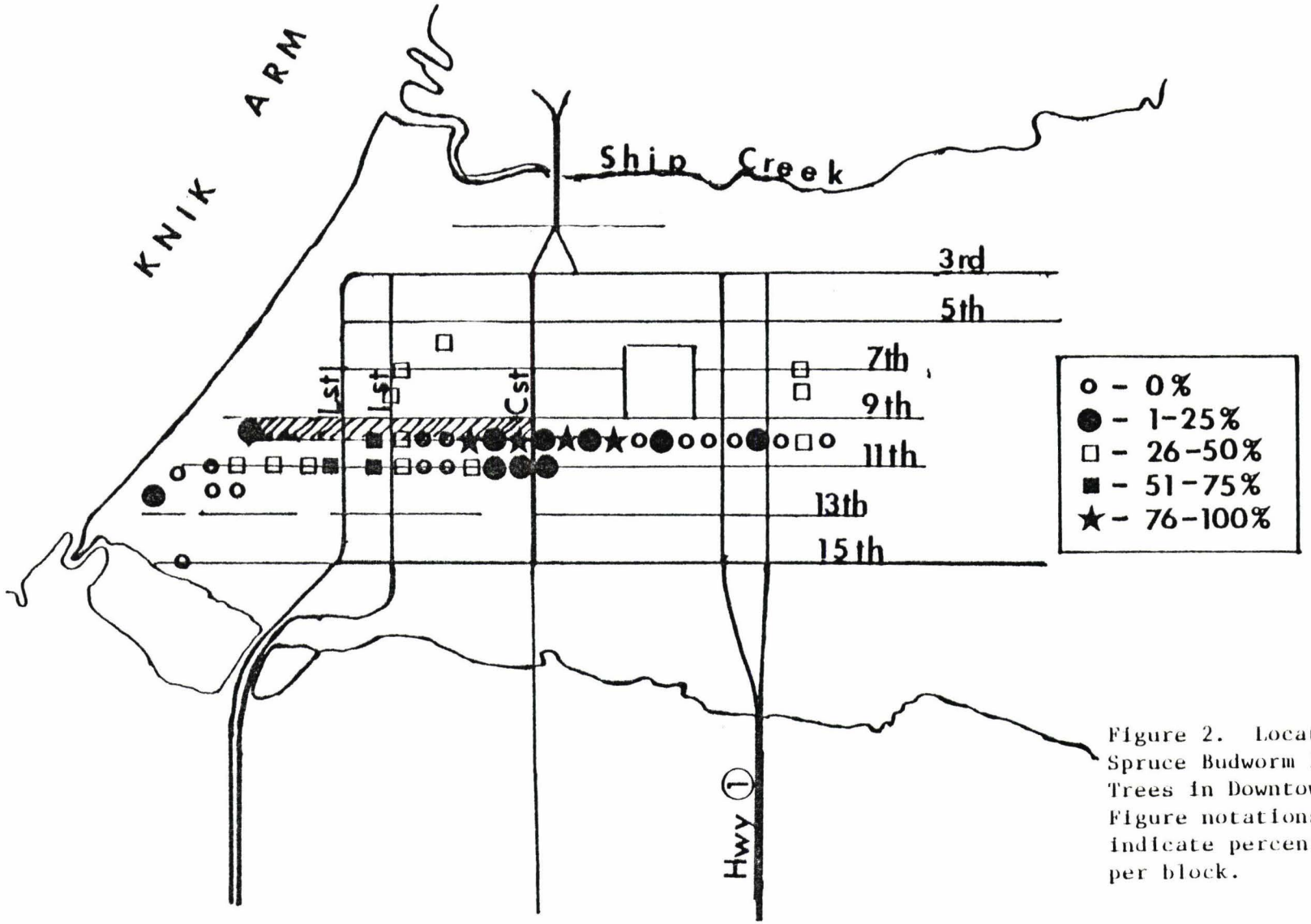

Figure 2. Location of Spruce Budworm Infested Trees in Downtown Anchorage. Figure notations (0, ●, etc) indicate percent infestation per block.

SUMMARY

Increased spruce budworm activity was detected in Anchorage residential areas beginning in 1978. Consequent studies have indicated that a species complex exists: C. biennis in low numbers plus one or more of the following species; C. occidentalis, C. orae and C. fumiferana. To date, budworms have been collected from Cooper Landing and Hope (Kenai Peninsula), Anchorage, Copper River Basin and Fairbanks. No visible damage has been detected in these areas with the exception of Anchorage.

Regardless of the species determinations, budworms have an adverse aesthetic effect in urban situations. The budworm may or may not be a forest problem depending upon the species determination(s). If the budworms are only C. biennis (the two-year budworm) the effects of defolation will be minimal under forest conditions.

CONTROL ALTERNATIVES

Spruce budworm suppression is not warranted on forested land at this time. However, under urban conditions, the spruce budworm can become much more devastating in terms of affecting host vigor and aesthetics.

Accordingly, the home owner may select either of two viable control alternatives. The choice of one or the other depends on the value of the tree, the health of the tree, the history of infestation and the degree of damage inflicted upon the host trees by budworm populations.

Alternative 1: Doing nothing to alleviate the pressure of budworm attack on spruce is an option and, in many cases, a viable one. If spruce trees are cared for (fertilization 1/), minimization of soil compaction, etc.) budworm damage to host tree vigor is minimal; at worst, resulting in limited branch dieback and temporary growth reduction.

Alternative 2: If ornamental spruce have shown signs of heavy budworm feeding and top or branch dieback is apparent, chemical treatment may be warranted. Insecticides should be applied from mid-May to early June when budworms are beginning to feed on expanding new growth. Young larvae are susceptible to chemical treatment at this time and damage can be minimized.

There are a number of insecticides containing Carbaryl, Dimethoate and Malathion registered by the Environmental Protection Agency for spruce budworm suppression.

1/ - 3 lbs. of fertilizer per one inch of base diameter should be placed around the dripline for adequate root feeding. Fertilization should begin in spring and be carried out through the growing season.

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Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key-out of the reach of children and animals-and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticie sprays or dusts; wear protective clothing and equipment if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

NOTE: Registrations of pesticides are under constant review by the Environmental Protection Agency and the Department of Agriculture. Use only pesticides that bear a Federal registration number and carry directions for home and garden use.

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